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Hospitalization Risk Among Older Adults with Sensory Impairments: Development of a Prognostic Model

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Abstract

OBJECTIVES: To develop a prognostic model for hospital admissions over a 1-year period among community-dwelling older adults with self-reported hearing and/or vision impairments based on readily obtainable clinical predictors.

DESIGN: Retrospective cohort study.

SETTING: Medicare Current Beneficiary Survey from 1999 to 2006.

PARTICIPANTS: Community-dwelling Medicare beneficiaries, aged 65 years and older, with self-reported hearing and/or vision impairment (N = 15,999).

MEASUREMENTS: The primary outcome was any hospital admission over a predefined 1-year study period. Candidate predictors included demographic factors, prior healthcare utilization, comorbidities, functional impairment, and patient-level factors. We analyzed the association of all candidate predictors with any hospital admission over the 1-year study period using multivariable logistic regression. The final model was created using a penalized regression method known as the

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article.

least absolute shrinkage and selection operator. Model performance was assessed by discrimination (concordance statistic (c-statistic)) and calibration (evaluated graphically). Internal validation was performed via bootstrapping, and results were adjusted for overoptimism.

RESULTS: Of the 15,999 participants, the mean age was 78 years and 55% were female. A total of 2,567 participants (16.0%) had at least one hospital admission in the 1-year study period. The final model included seven variables independently associated with hospitalization: number of inpatient admissions in the previous year, number of emergency department visits in the previous year, activities of daily living difficulty score, poor self-rated health, and self-reported history of myocardial infarction, stroke, and nonskin cancer. The c-statistic of the final model was 0.717. The optimism-corrected c-statistic after bootstrap internal validation was 0.716. A calibration plot suggested that the model tended to overestimate risk among patients at the highest risk for hospitalization.

CONCLUSION: This prognostic model can help identify which community-dwelling older adults with sensory impairments are at highest risk for hospitalization and may inform allocation of healthcare resources.

Keywords

sensory impairment; hearing impairment; vision impairment; hospitalization; prediction model

INTRODUCTION

Sensory impairments are highly prevalent in older adults, with around one in nine adults aged 80 years and older reporting hearing and vision impairment combined.[1] Hearing and vision impairments alone and in combination are independently associated with numerous adverse health outcomes, including reduced quality of life, higher rates of cognitive impairment, poor physical functioning, and increased risk of hospitalization.[1–4] Hospitalization often represents a sentinel event among older adults that precipitates functional decline, which is particularly true among those with sensory impairments who are at high risk of hospital-associated delirium.[5] Therefore, promoting interventions, such as treatment of hearing and/or vision loss, that may help to reduce hospitalization is important to prevent these adverse outcomes and promote healthy aging.[6] Risk prediction models can guide clinical decision-making and allocation of healthcare resources by providing estimates of which patients are at highest risk for hospitalization. Multiple models have been developed to predict risk of hospital admission among community-dwelling older adults, although none has specifically looked at a population with sensory impairments.[7–11] This is largely because there are few prospective cohorts with sufficient information about sensory impairments that also have adequate data on outcomes related to healthcare utilization. To address this issue, we developed a prognostic model for hospital admissions among participants with self-reported hearing and/or vision impairment using data from the Medicare Current Beneficiary Survey (MCBS).

METHODS

Participants

The MCBS is a continuous survey of a nationally representative sample of Medicare beneficiaries that links to healthcare utilization claims data.[12] Participants included in this study were community dwelling, aged 65 years and older, and had self-reported hearing and/or vision impairment at the start of the study period. We defined hearing impairment based on two self-reported questions: (1) Which statement best describes your hearing (with a hearing aid, if you use one)? (no trouble, a little trouble, or a lot of trouble) and (2) Do you use a hearing aid (yes, no, or deaf)? If participants reported "a little trouble" or "a lot of trouble" or if they used hearing aids or indicated deafness, they were classified as hearing impaired. Vision impairment was defined based on one self-reported question: "How much trouble do you have with your vision?" (no trouble, little trouble, or a lot of trouble). Participants who reported "little trouble" or "a lot of trouble" were classified as visually impaired. We did not define vision impairment based on use of glasses or contacts because 83% of participants in the MCBS cohort reported using glasses, suggesting poor measure sensitivity. The final cohort included 15,999 participants of a total population of 24,009 participants interviewed between 1999 and 2006.

Measures

We defined periods of 2-year units between the index years of 1999 to 2006, where the first year of the 2-year study units allowed us to look back on certain predictors, such as emergency department (ED) visits and hospital admissions. Our primary outcome was whether the participant had any hospital admission during the second year of the 2-year study units. The primary outcome was verified by Centers for Medicare & Medicaid Services claims codes. Candidate predictors were chosen based on prior research suggesting an association between sensory impairments and hospital admissions.[7,10] These included sociodemographic factors (age, sex, race, education, and income), healthcare use (hospital admissions and ED visits in the first year), self-reported comorbidities (myocardial infarction, stroke, diabetes mellitus, nonskin cancer, dementia, osteoporosis, hypertension, emphysema, osteoarthritis, Parkinson's disease, and rheumatoid arthritis), functional impairment (difficulty with activities of daily living (ADLs) and instrumental ADLs), and patient-level factors (barriers to receiving care, satisfaction with health care received, and self-rated health). To measure ADL difficulty, participants were asked questions about having any difficulty doing the following tasks by themselves and without special equipment: eating, toileting, dressing, bathing/showering, walking, and getting in or out of bed/chairs. The number of items that participants had difficulty with were added up to create an ADL difficulty score (range = 0–6). Self-rated health was assessed as a single item by asking participants to compare their health to others of the same age. Responses were classified as fair or poor versus excellent, very good, or good. For additional details on how variables were defined, see Supplementary Appendix S1.

Statistical Analysis

Descriptive statistics comparing participants with sensory impairments who did and did not have a hospital admission were presented as means for continuous variables or frequencies for categorical variables. To develop our prediction model, we analyzed the association of all a priori selected candidate variables with any hospital admission during the second year of the 2-year study unit using multivariable logistic regression.[13,14] We then developed a parsimonious model by using a penalized regression method known as the least absolute shrinkage and selection operator (LASSO).[15] We used 500 bootstrap samples and included those predictors that were retained in more than 60% of the bootstrapped samples.[16] As a separate analysis, we repeated this process in subsets stratified by type of sensory impairment (vision, hearing, and dual sensory impairment). Our results did not differ substantially, so we present the model in the full cohort, which had better precision due to larger sample size.

Model performance was assessed through discrimination and calibration. Discrimination was measured with the concordance statistic (c-statistic), which is equivalent to the area under the receiver operating characteristic curve. Calibration refers to the agreement between the observed risk of hospitalization and predicted risk. This was visually assessed through a calibration plot with the predicted proportion of hospitalization on the x axis and observed proportion of hospitalization on the y axis.[14] Model validation was performed to quantify any optimism in the prediction model. Internal validation using bootstrapping calculated the apparent performance as measured by the c-statistic on the bootstrap samples.[13] A Web application was built using R Shiny to calculate hospital admission risk based on a patient's specific characteristics.[17] All statistical analyses were performed using SAS statistical software, version 9.4 (SAS Institute, Inc). Further details of the design are provided in the supplement.

RESULTS

The baseline characteristics of the 15,999 participants included in this study are summarized in Table 1. The mean age was 78 years, and 55% were female. Of the total sample, 2,567 participants (16.0%) had at least one hospital admission in the second year of the 2-year study unit. Compared with those who were not hospitalized in the second year, participants who were hospitalized were more likely to have a hospitalization in the first year (mean = 0.51 vs 0.10), have an ED visit in the first year (mean = 0.76 vs 0.42), have higher ADL difficulty score (mean = 0.83 vs 0.50), report poor self-rated health (35.5% vs 21.9%), and report more comorbidities.

The final model after using the LASSO technique included seven variables: number of inpatient admissions in the previous year, number of ED visits in the previous year, ADL difficulty score, poor self-rated health, and self-reported history of myocardial infarction, stroke, and nonskin cancer (Table 2). The c-statistic was 0.717. After bootstrap internal validation was performed, the optimism-corrected estimate of the c-statistic was 0.716. A calibration plot is shown in Supplementary Figure S1. Sample calculations are provided in Figure 1 that demonstrate the range of risk for patients with hypothetical baseline characteristics. To allow for individualized predictions, a Web application (https://mcbspredictionmodel.shinyapps.io/shinyapp/) and Excel spreadsheet are provided as supplements (Supplementary Figure S2).

DISCUSSION

We developed a prognostic model for risk of 1-year inpatient admission in a cohort of community-dwelling older adults with self-reported hearing and/or vision impairment. In our final model, predictors of inpatient admissions included number of inpatient admissions in the previous year, number of ED visits in the previous year, ADL difficulty score, self-rated health, and comorbidities, including self-reported history of myocardial infarction, stroke, and nonskin cancer. Many of the variables included in our final model are consistent with previous studies, particularly those related to healthcare utilization and specific medical diagnoses.[7,10] For example, one commonly used score that estimates hospitalization risk is the Probability of Repeated Admission score, which includes age, sex, poor self-rated health, availability of an informal caregiver, history of coronary artery disease, diabetes mellitus in the previous year, hospital admission during previous year, and more than six physician visits during previous year.[11,18] Our model also looked at several variables less frequently included in prediction models, including those related to self-reported functional scores, access to care, and social support.[7,10] We included these because older adults with sensory impairments represent a particularly vulnerable patient population as they often have higher rates of social isolation and depression, increased physical disability, and higher healthcare utilization.[19–22] We found that ADL difficulty score and self-rated health contributed meaningfully to overall model performance, highlighting the importance of measuring patient-level and functional variables in vulnerable patient populations.

The model had good discrimination, with a c-statistic of 0.717, which is similar to other models of hospital admission.[9,10] The primary advantage of using this model relates to an intentional difference in case mix, meaning that the predicted probabilities will apply specifically to community-dwelling older adults with sensory impairments who are underrepresented in general models. There was little evidence of overoptimism in bootstrap validation. The calibration plot suggests that the model tends to overestimate risk among patients at the highest risk for hospitalization.

Given the dramatic impact of hospitalizations on healthcare spending and functional decline, an emphasis has been placed on identifying interventions that can help meet the complex needs of older adults with multimorbidity. In community settings, interventions that target specific risk factors or functional abilities may be more effective at improving patient-reported and functional outcomes compared with broad organizational interventions.[23,24] Among those with sensory impairments, sensory restorative services (e.g., hearing aids or cataract surgery) and sensory rehabilitative services (e.g., customization and counseling) have been associated with improved sensory-specific and general health-related quality of life.[25–27] However, many older adults do not receive these interventions due to a lack of screening for sensory deficits, perceptions among patients and healthcare professionals that sensory impairments are a normal part of aging, limited access to services, and often high out-of-pocket cost.[26,28,29] Tools such as this prediction model, which can readily be calculated through a patient or caregiver interview, may help inform efforts to get these therapies to people who stand to benefit the most. In turn, sensory restorative procedures, rehabilitation programs, and increased care coordination at home can help to improve function and independence to hopefully prevent adverse health outcomes, such as hospitalizations or ED visits.[30] For this tool to work optimally, efforts to increase screening for sensory impairments and reducing barriers to accessing sensory services will be needed.

There are a few important limitations in the development and validation of this prognostic model. First, sensory impairments and comorbidities were based on self-report rather than objective measurements. Subjective measures of sensory impairment are important in their own right because they capture the perceived quality of sensory impairment that likely impacts healthcare outcomes. Second, information on certain sensory-specific elements, such as the severity of sensory impairment, access to corrective devices, and utilization of sensory rehabilitation services, was not available. Consideration of these factors might enhance future predictive models. Third, we only included community-dwelling older adults in our population sample. Therefore, this model does not apply to those in assisted living or long-term care facilities. Fourth, although this model was internally validated, future research should focus on externally validating the model using a different cohort of older adults with sensory impairments to determine its generalizability. In addition, a competing risk analysis could be performed that incorporates time to death, which may help with obtaining more accurate predictions among those in the highest-risk strata.

In summary, older adults with sensory impairments are an increasingly prevalent and underrecognized vulnerable population that are at high risk for adverse health outcomes and contribute greatly to healthcare cost and utilization. Our model suggests that many of the previously identified predictors of hospital admissions among community-dwelling older adults apply to those specifically with sensory impairments. We hope that this tool will help provide clinicians and patients with prognostic information that can guide clinical decisions and inform allocation of healthcare resources.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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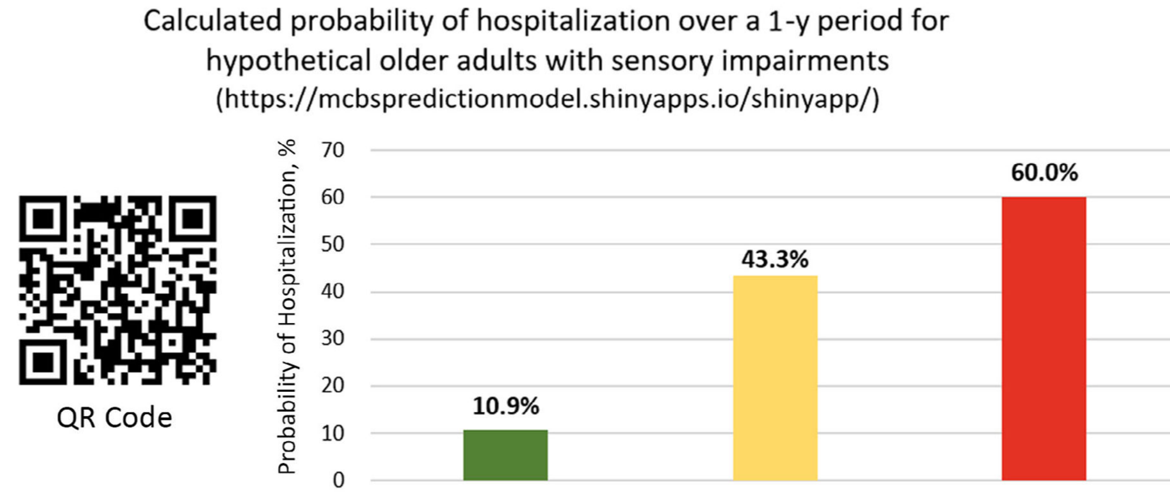

	Patient 1	Patient 2	Patient 3
No. of inpatient admissions in previous year	0	1	1
No. of ED visits in previous year	1	2	2
History of myocardial infarction	No	No	Yes
History of nonskin cancer	No	Yes	No
History of stroke	No	No	Yes
ADL difficulty score (range = 0-6)	1	2	3
Poor self-rated health	No	Yes	Yes

Figure 1.

Hypothetical patient examples with the prediction model's calculated probability of hospitalization over a 1-year period. ADL, activity of daily living; ED, emergency department.

Table 1.

Baseline Characteristics of Participants with Self-Reported Hearing and/or Vision Impairment Stratified by Those Hospitalized and Not Hospitalized in the 1-Year Study Period

Characteristic	Hospitalized (n = 2,567)	Not hospitalized (n = 13,432)	*P* value
Age, mean (SD), y	78.7 (7.2)	77.3 (7.2)	<.001
Female, %	54.1	55.8	.12
Black race, %	12.2	12.4	.73
Annual income <$10,000, %	25.1	22.0	.007
Never graduated from high school, %	36.3	31.1	<.001
Lives alone, %	36.2	36.0	.88
Medicaid insurance coverage eligible, %	15.5	12.1	<.001
No. of inpatient admissions in the first of the 2-y study period, mean (SD)	0.51 (0.91)	0.10 (0.40)	<.001
No. of ED visits in the first of the 2-y study period, mean (SD)	0.76 (2.47)	0.42 (1.16)	<.001
ADL difficulty score, mean (SD) (range = 0–6)	0.83 (1.13)	0.50 (0.91)	<.001
IADL difficulty score, mean (SD) (range = 0–6)	1.09 (1.26)	0.73 (0.71)	<.001
Poor self-rated health, %	35.5	21.9	<.001
Self-reported trouble getting health care, %	6.0	5.6	.46
Dissatisfied with quality of health care received, %	4.3	5.4	.02
Self-reported comorbidities, %			
Myocardial infarction	26.7	14.3	<.001
Stroke	20.5	12.6	<.001
Cancer (excluding skin cancer)	26.8	19.8	<.001
Dementia	6.2	4.1	<.001
Diabetes mellitus	26.6	19.8	<.001
Osteoporosis	21.9	21.3	.49
Hypertension	69.7	64.0	<.001
Emphysema	20.4	15.1	<.001
Osteoarthritis	69.4	63.9	<.001
Parkinson's disease	2.5	1.8	.02
Rheumatoid arthritis	13.7	11.4	.001
Type of sensory impairment			

Characteristic	Hospitalized (n = 2,567)	Not hospitalized (n = 13,432)	*P* value
Vision impairment only	16.4% Hospitalized		
Hearing impairment only	13.8% Hospitalized		
Vision and hearing impairment	17.8% Hospitalized		

Abbreviations: ADL, activity of daily living; ED, emergency department; IADL, instrumental ADL; SD, standard deviation.

Table 2.

Multivariable-Adjusted Prognostic Factors for 1-Year Inpatient Admission After Using the Least Absolute Shrinkage and Selection Operator

Factor	β Coefficient	Odds ratio	95% CI
No. of inpatient admissions in previous year	.93	2.53	2.35–2.72
No. of ED visits in previous year	.07	1.08	1.05–1.11
History of myocardial infarction	.56	1.75	1.57–1.95
History of cancer (other than skin cancer)	.31	1.36	1.23–1.51
History of stroke	.26	1.29	1.14–1.45
ADL difficulty score (range = 0–6)	.17	1.18	1.13–1.24
Poor self-rated health	.36	1.43	1.23–1.57

Note: The concordance statistic (c-statistic; area under the receiver operating characteristic curve) = 0.717.

Optimism-corrected c-statistic after bootstrap validation = 0.716.

Abbreviations: ADL, activity of daily living; ED, emergency department.